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TI **Pearlitic** steel rail having high abrasion resistance and high resistance to inside fatigue damage and its production method
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AB The title rail contains **C** >0.85 but ≤1.20, **Si** 0.10-1.00, **Mn** 0.10-1.50, V 0.01-0.20, and optionally ≥1 of **Cr** 0.05-1.00, **Mo** 0.01-0.20, **Cu** 0.05-0.5, **Ni** 0.05-1.00, Nb 0.002-0.050, Ti 0.0050-0.0300, Mg 0.0010-0.0100, Ca 0.0010-0.0150, and Co 0.10-2.00%, and balance **Fe** and has a **pearlite** structure with Vickers hardness of 360-480 at the head corner section and the range up to the depth of at least 20 mm from the vertex surface, wherein the difference of Vickers hardness is <40. The head section of rail at a temperature higher than Ar1 or Ac1+30°, obtained from steel having the above composition, is acceleration cooled from the austenite region temperature at a cooling rate of 1-15°/s, and the acceleration cooling is stopped when the rail head temperature reaches 450-650° followed by naturally cooling.

0.85 - 1.2 C

0.1 - 1 Si

0.1 - 1.5 Mn

0.05 - 1.0 Ni

0.05 - 1 Cr

0.01 - 0.2 Mo

0.05 - 0.5 Cu

Fe

1 - 8, 12, 16, 17

PATENT ABSTRACTS OF JAPAN

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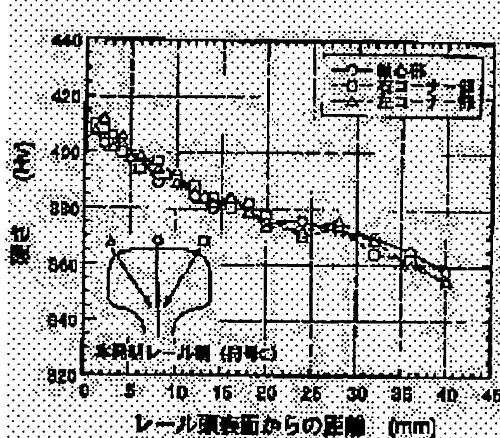
(54) PEARLITIC RAIL EXCELLENT IN WEAR RESISTANCE AND RESISTANCE TO INTERNAL FATIGUE DAMAGE, AND ITS MANUFACTURE

(57)Abstract:

PROBLEM TO BE SOLVED: To reduce a hardness difference in the cross section of a railhead and to improve the wear resistance and internal fatigue damage resistance of a high-load railroad rail by adding V and further N to a hyper-eutectoid steel.

SOLUTION: The pearlitic rail excellent in resistance to wear and internal fatigue damage is a steel rail which has a composition containing, by mass, >0.85-1.20% C, 0.10-1.00% Si, 0.10-1.50% Mn, 0.01-0.20% V, and further 0.0060-0.0500% N and also containing, if necessary, Cr, Mo, Cu, Ni, Nb, Ti, Mg, Ca, and Co. In this steel rail, the region from the surface of railhead corners and a railhead to the position at a depth of at least 20 mm from the surface has a pearlitic structure.



Further, the hardness of the pearlitic structure in the above region is regulated to Hv 360 to 480, and the difference in the hardness is regulated to ≤ Hv 40. The rail can be manufactured by applying accelerated cooling to the railhead of a high temperature steel rail.

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DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] This invention relates to the pearlite system rail which raised the abrasion resistance and the interior fatigue damage nature of -proof which are required of the rail of a heavy loading railroad, and its manufacturing method.
[0002]
[Description of the Prior Art] On the overseas heavy loading railroad, improvement in a train rate and train loading weight increase are planned as a means of efficient-izing of railroad transportation. Much more improvement of the rail quality of the material has come [the increase in efficiency of such railroad transportation meant severe-ization of a rail operating environment, and] to be required. By the rail laid at the curvilinear section, wear of the G.C. (gage corner) section or a head flank increases rapidly, and, specifically, came to be regarded as questionable in respect of the use life of a rail.
[0003] However, the high intensity (high degree of hardness) rail as shown in the following which presented the fine pearlite organization using eutectoid carbon steel by advance of the latest high intensity-ized heat treatment technique was invented, and the rail life of the curvilinear section of a heavy loading railroad has been improved by leaps and bounds.
** The heat-treated rail for super-****** of sorbite or a detailed pearlite organization in a head (JP,54-25490,B).
** The manufacturing method of two or more 130 kgf(s)/mm high intensity rails which carry out accelerated cooling of for 850-500 degrees C after rolling termination or for the rail head which reheated by 1-4 degrees C/sec from austenite region temperature (patent No. 1597914).
The description of these rails was a high intensity rail which presents the fine pearlite organization by eutectoid carbon content steel (carbon content: 0.7 - 0.8%), and the place made into the purpose made lamellae spacing under pearlite organization detailed, and suited at the place which raises abrasion resistance.
[0004] However, high loading-ization of a cargo is powerfully advanced for efficient-izing of much more railroad transportation, and by the rail of a sudden curve, even if it uses the rail of the above-mentioned development, the abrasion resistance of the G.C. section or a head flank cannot secure enough, but the fall of the rail life by wear has posed a problem especially on the overseas heavy loading railroad in recent years. From such a background, development of the rail which has the abrasion resistance more than the high intensity rail of the present eutectoid carbon steel has come to be called for.
[0005] In order to solve these problems, this invention persons developed the rail as shown below.
** The rail which was excellent in the abrasion resistance to which the cementite consistency in the lamellae under pearlite organization was made to increase using hypereutectoid steel (C:0.85 ** -1.20%) (JP,8-144061,A official report)

** The rail excellent in the abrasion resistance which was made to increase the cementite consistency in the lamellae under pearlite organization, and controlled hardness to coincidence using hypereutectoid steel (C:0.85 ** -1.20%) (JP,8-246100,A official report)
The description of these rails was what increases the carbon content of steel, is made to increase the consistency of the cementite phase excellent in the abrasion resistance in pearlite lamellae, and raises the abrasion resistance of a pearlite organization by controlling hardness further.
[0006] Furthermore, this invention persons developed the rail as shown in the following which raised the abrasion resistance of a rail head, and the interior fatigue damage nature of -proof using hypereutectoid steel with a high carbon content.
** The rail which raised abrasion resistance and the interior fatigue damage nature of -proof by adding B to hypereutectoid steel (C:0.85 ** -1.20%) (Japanese-Patent-Application-No. No. 527465 [eight to] official report).
the description of this rail promotes a pearlite transformation by adding minute amount B to hypereutectoid steel -- making -- the more uniform degree-of-hardness distribution from a rail head front face to the interior -- giving -- the abrasion resistance of a rail, and the interior fatigue damage nature of -proof -- it was what is raised greatly.
[0007]
[Problem(s) to be Solved by the Invention] Although it is expected that the invention rail shown in the above-mentioned ** has abrasion resistance and the interior fatigue damage nature of -proof by adding minute amount B to hypereutectoid steel (C:0.85 ** -1.20%) excellent in abrasion resistance, and contributes them to high life-ization of the rail for heavy loading railroads most Depending on the difference in the component system of steel, it only added and ordered B to hypereutectoid steel, and it became clear then that the facilitatory effect of a pearlite transformation may not fully be acquired and uniform degree-of-hardness distribution may not be acquired from a rail head front face to the interior.
[0008] Then, this invention persons examined the alloying element which replaces B by experiment in order to solve this trouble. As a result of conducting the accelerated cooling experiment of the rail head using a real rail, as compared with the heading part, by adding V to hypereutectoid steel, the carbide of V tended to deposit on the ferrite background under par rye flume organization, and it was checked inside the rail head where a cooling rate is slow that the degree of hardness inside a rail head improves.
[0009] Furthermore, this invention persons examined the element which raises the effectiveness of V further by the above-mentioned experiment. consequently, addition of V -- in addition, the carbide of V which deposits on the ferrite background under par rye flume organization of hypereutectoid steel by carrying out compound addition of the N -- in addition, the nitride of V deposited and it was checked that the degree of hardness inside a rail head improves sharply. It checked that this invention persons could enable improvement in a degree of hardness also in the interior of a rail head, and could raise abrasion resistance and the interior fatigue damage nature of -proof from the above experimental result to coincidence V and by adding N in addition to V further instead of addition of B to hypereutectoid steel.
[0010] In addition, this invention persons examined the heat treatment conditions for attaining V and high intensity-ization of the steel rail which added N further in addition to V by experiment. Consequently, in order not to make abnormal structure, such as martensite, generate in a heading part, but to have made the pearlite organization excellent in abrasion resistance generate stably, to have deposited the carbide and the nitride of V in the interior of a rail head in coincidence and to have aimed at improvement in a degree of hardness, it checked that the fixed range existed in the cooling rate of a heading part.
[0011] In order that this invention persons may raise the abrasion resistance of the rail for heavy loading railroads, and the interior fatigue damage nature of -proof, the carbon content of

rail steel is made to increase from the above result first. To coincidence to V and a pan By making the carbide and the nitride of V generate stably, in addition performing accelerated cooling heat treatment by adding N in addition to V The knowledge of the ability to manufacture the high intensity rail excellent in abrasion resistance and the interior fatigue damage nature of -proof with high degree-of-hardness distribution uniform from a rail head front face to the interior was carried out.

[0012] That is, the purpose of this invention is related with the pearlite system rail aiming at raising the abrasion resistance required of the rail of a heavy loading railroad, and raising the interior fatigue damage nature of -proof stably to coincidence, and its manufacturing method.

[0013]

[Means for Solving the Problem] The place which this invention attains the above-mentioned purpose and is made into the summary is as follows.

(1) At mass %, it is C. : 0.85 ** -1.20%, Si: 0.10-1.00%, Mn:0.10-1.50%, V 0.02 - 0.20% is contained and the need is accepted further. : [Cr:0.05-1.00%,] Mo: 0.01-0.20%, Cu:0.05-0.50%, nickel: 0.05-1.00%, Nb:0.002-0.050% Ti:0.0050-0.0300%, Mg: The pearlite system rail excellent in the abrasion resistance and the interior fatigue damage nature of -proof which are characterized by containing one sort (0.0010-0.0100%, calcium:0.0010-0.0150%, and Co:0.10-2.00%) or two sorts or more, and the remainder consisting of Fe and an unescapable impurity.

(2) At mass %, it is C. : 0.85 ** -1:20%, Si: 0.10-1.00%, Mn:0.10-1.50%, V : 0.02 - 0.20%, N : 0.0060 - 0.0500% is contained and the need is accepted further. Cr:0.05-1.00%, Mo: 0.01-0.20%, Cu:0.05-0.50%, nickel: 0.05-1.00%, Nb:0.002-0.050% Ti:0.0050-0.0300%, Mg: The pearlite system rail excellent in the abrasion resistance and the interior fatigue damage nature of -proof which are characterized by containing one sort (0.0010-0.0100%, calcium:0.0010-0.0150%, and Co:0.10-2.00%) or two sorts or more, and the remainder consisting of Fe and an unescapable impurity.

(3) the pearlite system rail excellent in the abrasion resistance and the interior fatigue damage nature of -proof which be characterize by consider as the pearlite organization whose range of 20mm depth be the rail which have a component the above (1) or given in (2), and be the range of hardness 360-Hv 480 at least considering the head corner section and the parietal region front face of said steel rail as an origin and, whose difference of the hardness be 40 or less Hv.

(4) The steel rail head of the temperature of one or more Ar(s) of a hot rolling as which consists of a component the above (1) or given in (2), Or the steel rail head heated by one Ac temperature of +30 degrees C or more in order to heat-treat Carry out accelerated cooling with the cooling rate of 1-15 degrees C/sec from austenite region temperature, when the temperature of the head of said steel rail attains 650-450 degrees C, stop accelerated cooling, and it cools radiationally after that. The range of 20mm depth at least the head corner section and the parietal region front face of said steel rail as an origin in the range of hardness 360-Hv 480 And the manufacture approach of a pearlite system rail excellent in the abrasion resistance and the interior fatigue damage nature of -proof which are characterized by considering as the pearlite organization whose difference of the hardness is 40 or less Hv.

[0014]

[The mode of implementation of invention] Hereafter, this invention is explained to a detail. In claims 1-12, the reason which limited the difference of the range of a chemical entity or a chemical entity, and a pearlite organization, hardness, and the hardness of a pearlite organization like the above-mentioned generic claim is explained to a detail.

[0015] (1) a part for ****** of rail steel -- explain first the reason which limited the chemical entity of a rail as mentioned above in this invention. Although it is the effective element which C makes promote a pearlite transformation and secures abrasion resistance and the 0.60 - 0.85% of the amounts of C is added as usual rail steel, at the 0.85% or less of the amounts of

C, the consistency of the cementite phase under pearlite organization for aim at wear-resistant improvement is not securable, further, it becomes easy to generate the grain boundary ferrite used as the origin of fatigue damage, and a rail life falls to the interior of a rail head. Moreover, when the amount of C exceeded 1.20%, depending on the component system, the free cementite organization generated during the pearlite organization, the consistency of that the toughness of a rail and ductility fall greatly and the cementite phase under pearlite organization increased, and since it became impossible to fully secure the ductility needed for a rail, the amount of C was limited to 0.85 ** -1.20%.
[0016] Although Si was an element which raises the degree of hardness (reinforcement) of a rail head by solid-solution hardening to the ferrite phase under pearlite organization, if the effectiveness was not fully able to expect and exceeded 1.00%, since weldability would fall by that many surface cracks generate at the time of hot rolling, and generation of an oxide, it limited the amount of Si to 0.10 - 1.00% at less than 0.10%.
[0017] Mn reduces the pearlite temperature of transformation and contributes to high intensity-ization by raising hardenability, further, although it is an element which controls generation of a free cementite organization, with less than 0.10% of content, the effectiveness is small and it becomes difficult to secure [of the hardness needed for a rail head] it. Moreover, if it exceeded 1.50%, since hardenability would increase remarkably, becoming easy to generate martensitic structure and a segregation would be promoted and it would become easy to generate a free cementite organization harmful to the toughness of a rail in the segregation section, the amount of Mn was limited to 0.10 - 1.50%.
[0018] Although it is the element which raises the degree of hardness inside a head by V's forming carbide and a nitride in heat treatment of a rail head inside the rail head where a cooling rate is slow as compared with a heading part, and depositing on the ferrite background under pearlite organization, at less than 0.01%, formation of a nitride or a nitride becomes difficult and precipitation hardening of the pearlite organization inside a rail head becomes difficult. Moreover, the addition of N in which the effectiveness beyond it not being expectable even if it adds exceeding 0.20%, and the nitride of V are made to form and which is the equivalent chemically exceeded 0.0500%, and since it became easy to generate the internal defect of the blowhole which serves as an origin of internal fatigue damage at the time of a molten steel ingot, the amount of V was limited to 0.01 - 0.20%.
[0019] Furthermore, since N is made to contain and the effectiveness of V may be heightened by the synergistic effect, it adds if needed. Although it is the element which raises further the degree of hardness inside the comparatively late rail head of a cooling rate by N's combining with V, forming the nitride of V, and depositing on the ferrite background under pearlite organization, at less than 0.0060%, generation of the nitride of V becomes difficult. Moreover, if it exceeded 0.0500%, since it would become easy to generate the internal defect of the blowhole which serves as an origin of internal fatigue damage at the time of a molten steel ingot, the amount of N was limited to 0.0060 - 0.0500%. In addition, in order to aim at the rise of the hardness inside a rail, to make the nitride of V generate stably and to control generating of the internal defect of a blowhole etc. to coincidence, it is desirable to make N addition into 0.0100 - 0.0200% of range.
[0020] Moreover, the rails manufactured by the above-mentioned component presentation are reinforcement, ductility, toughness, and the purpose that prevents ingredient degradation at the time of welding further, and add one kind or two sorts or more for the element of Cr, Mo, Cu, nickel, Nb, Ti, Mg, calcium, and Co if needed. here -- in high-intensity-izing, wear-resistant improvement, and nickel, Nb and Ti, ductility, toughness simultaneously reinforcement, improvement, and Cu and Co add Mg, and the improvement in on the strength and calcium add [Cr and Mo] improvement in ductility and toughness as main purposes.
[0021] Although it is the element which raises abrasion resistance by strengthening the

cementite phase under pearlite organization at the same time Cr raises the balanced transformation point of a pearlite, it makes a pearlite organization detailed as a result and it contributes to high intensity-ization At less than 0.05%, the effectiveness was small, and if superfluous addition exceeding 1.00% was performed, in order that martensitic structure might generate so much and might reduce the toughness of a rail, the amount of Cr(s) was limited to 0.05 - 1.00%.

[0022] Although it is the element which Mo raises the balanced transformation point of a pearlite like Cr, contributes to high intensity-ization by making a pearlite organization detailed as a result, and raises abrasion resistance The effectiveness was small, and at less than 0.01%, when superfluous addition exceeding 0.20% was performed, the segregation was promoted, and since a pearlite transformation rate fell, martensitic structure generated in the segregation section and the toughness of a rail fell, the amount of Mo was further limited to 0.01 - 0.20%.

[0023] Cu was an element which does not spoil the toughness of pearlite steel but raises reinforcement, and if the effectiveness was the largest in 0.05 - 0.50% of range and it exceeded 0.50%, since it would become easy to produce red-heat embrittlement, it limited the amount of Cu(s) to 0.05 - 0.50%.

[0024] Although it is the element which nickel raises the ductility of pearlite steel, and toughness and attains high intensity-ization of pearlite steel by solid solution strengthening to coincidence, at less than 0.05%, the effectiveness is remarkably small, and even if it performs superfluous addition exceeding 1.00%, effectiveness beyond it is not expectable. Therefore, the amount of nickel was limited to 0.05 - 1.00%.

[0025] Nb raises reinforcement by precipitation hardening by Nb carbide and Nb nitride like V, in case heat treatment heated to high temperature is performed further, an austenite grain is made to make it detailed according to the operation which controls grain growth, and rather than V, the austenite grain growth suppression effectiveness acts to a high temperature region (about 1200 degrees C), and improves the ductility of a pearlite organization, and toughness. At less than 0.002%, even if the effectiveness performs superfluous addition which cannot expect and exceeds 0.050%, it cannot expect effectiveness beyond it. Therefore, the amount of Nb(s) was limited to 0.002 - 0.050%.

[0026] Ti is a component effective in attaining detailed-ization of the austenite crystal grain at the time of rolling heating, and raising the ductility and the toughness of a pearlite organization using depositing Ti carbide and Ti nitride not dissolving, in reheating of rail pressure Nobutoki. However, at less than 0.0050%, if there is little the effectiveness and it adds exceeding 0.0300%, in order for big and rough Ti carbide and Ti nitride to generate, and for the origin of fatigue damage rail in use to come and to generate a crack, the amount of Ti was limited to 0.0050 - 0.0300%.

[0027] Mg is an element effective in combining with O or S, aluminum, etc., forming a detailed oxide, controlling grain growth of crystal grain in reheating of rail pressure Nobutoki, attaining detailed-ization of an austenite grain, and raising the ductility and the toughness of a pearlite organization. Furthermore, it is an element effective in raising the ductility and the toughness of a pearlite organization by MgO and MgS distributing MnS minutely, forming the thin band of Mn in the perimeter of MnS, and contributing to generation of a pearlite transformation, consequently making a pearlite block size detailed. However, at less than 0.0010%, if it was weak and added exceeding 0.0100%, in order that the big and rough oxide of Mg might generate the effectiveness and it might degrade rail ductility and toughness, it limited the amount of Mg to 0.0010 - 0.0100%.

[0028] calcium is an element effective in raising the ductility and the toughness of a pearlite organization by bonding strength with S being strong and forming a sulfide as CaS, and CaS's distributing MnS minutely, forming the thin band of Mn in the perimeter of MnS further, and

contributing to generation of a pearlite transformation, consequently making a pearlite block size detailed. However, at less than 0.0010%, if it was weak and added exceeding 0.0150%, in order that the big and rough oxide of calcium might generate the effectiveness and it might degrade rail ductility and toughness, it limited the amount of calcium to 0.0010 - 0.0150%.
[0029] Although Co was an element which raises reinforcement by making the transformation energy of a pearlite increase and making a pearlite organization detailed, since the effectiveness arrived at a saturation region even if it performs superfluous addition which cannot expect the effectiveness and exceeds 2.00%, it limited the amount of Co(es) to 0.10 - 2.00% at less than 0.10%.
[0030] The rail steel which consists of above component presentations ingots with fusion furnaces usually used, such as a converter and an electric furnace, and ingot making and a cogging method or a continuous casting process, and a pan manufacture this molten steel as a rail through hot rolling. Next, it becomes possible to make a rail head generate stably the pearlite organization where hardness is high by heat-treating on the rail head reheated by the elevated temperature for the rail which holds the heat of this hot-rolled high temperature, or the purpose to heat-treat.
[0031] (2) Explain the reason which limited the desirable hardness of a pearlite organization to the range of Hv 360-480 at the beginning of the desirable hardness of a pearlite organization, and its range. If hardness is set to less than 360 Hv by this component system, wear of a rail will advance, it will become difficult to secure the abrasion resistance demanded on the heavy loading railroad, and it will further become easy to generate a fatigue crack from the interior of a head by the rail used in the sudden curvilinear section. moreover, the thing which concordance nature with the wheel of a heading part will fall, and will be become easy to generate a surface damage if hardness exceeds Hv480 -- moreover, in rail heat treatment manufacture, in order for abnormal structure, such as bainite and martensite, to generate on a rail head and to reduce the abrasion resistance of a rail, and the interior fatigue damage nature of -proof on it, hardness was limited to the range of Hv 360-480.
[0032] Next, the reason which limited this head front face of the head corner section and the parietal region for the desirable range which the pearlite organization of the range of hardness 360-Hv 480 presents to the range of 20mm depth as an origin is explained. In less than 20mm, as the abrasion resistance needed for the rail head, and an interior fatigue damage nature field of -proof, it is small, and is because sufficient life improvement effect is not acquired according to advance of wear, and generating of internal fatigue damage. Moreover, if there is range which presents said pearlite organization a depth of 30mm or more considering this head front face of the head corner section and the parietal region as an origin, a life improvement effect increases further and is more desirable.
[0033] Here, the field by which the name and abrasion resistance in the head cross-section surface location of the rail excellent in the abrasion resistance of this invention and the interior fatigue damage nature of -proof are needed for drawing 1 is shown. In a rail head, 1 is the parietal region, 2 is the head corner section, and one side of the head corner section 2 is the gage corner (G. C.) section which mainly contacts a wheel. Moreover, if the pearlite organization of the range of hardness 360-Hv 480 is stationed at least in the shadow area in drawing, improvement in a rail use life of it will be attained.
[0034] (3) Explain to the difference last of the desirable hardness of a pearlite organization the reason which limited the maximum of the difference of the hardness of a desirable pearlite organization in the range of 20mm depth to 40 or less Hv. In a rail head, since a cooling rate changes at least with each part of a cross section, generally hardness shows the distribution which falls as it goes to the interior of a head from a heading part. If the hardness difference inside this rail head front face and a head exceeds Hv40, change of material strength will become remarkably large in a rail head cross section. Since distortion (plastic deformation

field) generated from the external force which acts on a rail concentrated on the low degree-of-hardness (reinforcement) section inside a rail head in connection with this, consequently internal fatigue damage occurred and a rail life fell, the maximum of the difference of hardness was limited to 40 or less Hv.

[0035] (4) Explain to a detail the reason which limited heating at the time of rail manufacture, and cooling conditions as mentioned above in the manufacture approach of manufacture condition this invention. First, in order to obtain a predetermined organization and a predetermined degree of hardness, it is necessary to make a rail head fully austenitize at least, although it is the temperature conditions before cooling a rail head. In the rail head which is the temperature region of one or more Ar(s) in the rail head immediately after rolling, and was reheated, one Ac temperature of +30 degrees C or more is required for the temperature. In addition, although especially the upper limit of temperature is not specified, since the liquid phase will appear and an austenite phase will become unstable if it is made high temperature not much, as for temperature, 1350 degrees C of parenchyma serve as an upper limit.

[0036] It is the part which contains the rail parietal region (sign: 1) indicated to be the above-mentioned "rail head" to drawing 1 , and the head corner section (sign: 2) here. The range of 20mm depth (shadow area of drawing 2) can be represented at least, and the cooling rate and temperature which are explained below will become possible [the thing of a rail head for which the organization and degree of hardness of said part (shadow area of drawing 2) are controlled at least], if the depth measures in the range which is 2-5mm from the head front face of the rail parietal region (sign: 1) shown in said drawing 2 , and the head corner section (sign: 2). [0037] Next, in the approach of carrying out accelerated cooling of the between from austenite region temperature to 650-450 degrees C for a rail head with the cooling rate of 1-15 degrees C/sec, the reason which limited accelerated cooling halt temperature as mentioned above is explained. If accelerated cooling was stopped at the temperature exceeding 650 degrees C, since a pearlite transformation began immediately after accelerated cooling, the pearlite organization where hardness is low generated mostly, the hardness of a rail head was set to less than 360 Hv and neither abrasion resistance nor the interior fatigue damage nature of -proof was able to be secured, it limited to 650 degrees C or less. Moreover, when accelerated cooling was performed to less than 450 degrees C, sufficient recuperation from the interior of a rail was not expectable after accelerated cooling, and in order that martensitic structure harmful to the toughness of a rail and the interior fatigue damage nature of -proof might generate in the segregation section inside a rail head etc., it limited to 450 degrees C or more.

[0038] Moreover, if the accelerated cooling rate of a rail head becomes under 1 degree C / sec, a pearlite transformation will begin in the high temperature region in the middle of accelerated cooling. The pearlite organization where hardness is low generates mostly, and the hardness of a rail head is set to less than 360 Hv. That reservation of the abrasion resistance of a rail head and the interior fatigue damage nature of -proof becomes difficult, and in order that a free cementite organization harmful to the toughness of a rail and ductility might generate depending on a component system, it limited 1 degree C / more than sec. If an accelerated cooling rate exceeds 15 degrees C/sec, in order for abnormal structure, such as bainite and a marte site, to generate on a rail head and to reduce abrasion resistance and the interior fatigue damage nature of -proof into accelerated cooling, without carrying out a pearlite transformation, the accelerated cooling rate was limited to the range of 1-15 degrees C/sec. In addition, in order to make the pearlite organization where a degree of hardness is high generate stably to the interior of a rail head, it is most desirable to make an accelerated cooling rate into the range of 5-10 degrees C/sec.

[0039] Although this accelerated cooling speed range limits the average cooling rate from cooling initiation to termination, a temporary temperature rise by generation of heat by pearlite

transformation or the natural recuperation from the interior of a rail may occur [in the middle of accelerated cooling]. However, if the average cooling rate from accelerated cooling initiation to termination is above-mentioned within the limits, since there is ****** about the big effect in the property of this pearlite system rail, it also includes the fall of the cooling rate accompanying a temporary temperature rise in the middle of cooling as accelerated cooling conditions for this rail. [no]
[0040] Moreover, it is possible to obtain a predetermined cooling rate with the cooling media which were mainly concerned with air or air and added Myst etc. as an approach of obtaining the cooling rate of 1-15 degrees C/sec, and such combination.
[0041] Therefore, in order to manufacture the rail excellent in the abrasion resistance and the interior fatigue damage nature of -proof which presented the 360 or more-Hv pearlite organization So that generation of the pearlite organization where hardness is low may be prevented and free cementite harmful to abrasion resistance, ductility, toughness, and the interior fatigue damage nature of -proof, martensite, and a bainite texture may not generate in a heading part By stopping accelerated cooling, when accelerated cooling is carried out with the cooling rate of 1-15 degrees C/sec from austenite region temperature using the refrigerant which was mainly concerned with air or air and added Myst etc. and the temperature of this steel heading part attains 650-450 degrees C It becomes possible to make the pearlite organization of a high degree of hardness generate stably from a heading part to the interior.
[0042] Radiationnal cooling, i.e., cool naturally, is desirable until it does not perform cooling with compulsory <the explanation important point of subsequent radiationnal cooling> and cooling after accelerated cooling but completes a pearlite transformation. in addition, a production disposition -- cooling, after a pearlite transformation completes in order to prevent generation of the organization which reduces the toughness of rails, such as martensitic structure, when cooling a rail compulsorily, since it is good -- ** -- better. In addition, in this component system, the temperature which the pearlite transformation of the whole rail head completes mostly is in the condition that the temperature of a rail head front face was cooled by less than 350 degrees C.
[0043] Although it is desirable that he is a pearlite organization as a metal texture of a rail, depending on a component system, an accelerated cooling rate, and the segregation condition of a material, a minute amount proeutectoid ferrite organization and a free cementite organization may generate during a pearlite organization. However, even if these organizations generate during a pearlite organization at a minute amount, since there is nothing ****** about the big effect about the abrasion resistance, the ductility, the toughness, the interior fatigue damage nature of -proof, and reinforcement of a rail, as an organization of this pearlite system rail, mixture of some proeutectoid ferrite organization and a free cementite organization is also included.
[0044]
[Example] Next, the example of this invention is explained. The chemical entity, the head accelerated cooling conditions, the rail head axial center section hardness, and the head microstructure of this invention rail steel are shown in Table 1. Moreover, the rolling fatigue test result shown in the abrasion loss after the 700,000 times repetition by Nishihara style abrasion test under the forced-cooling conditions shown in Table 1 at drawing 2 and drawing 3 was also written together.
[0045]
[Table 1]

レール	符号	化学成分 (mass%) C	Si	Mn	V	N	Cr/Mo/Cu/Ni/Nb Ti/Mg/Ca/Co	頭部加速冷却条件 冷却速度 (℃/sec)	停止温度 (℃)	頭部軸心部硬さ (Hv 10kgf) 頭表部 (1 mm点)	頭部内部 (20mm点)	硬度差	頭部ミクロ組織 表：頭表部 1mm点 内：頭部内部20mm点	頭部材料摩耗量 (g)	転動疲労試験結果 内部疲労損傷発生の有無 $(\times 10^7)$
本発明レール鋼	A	0.85	0.61	1.38	0.05	0.0039	Mg:0.0017	5	520	414	384	30	表：パーライト 内：パーライト	0.96	実用上問題となる損傷の発生なし（0.85回：微小き裂発生）
	B	0.87	0.45	1.25	0.08	0.0087	Co:0.22	4	556	400	378	22	表：パーライト 内：パーライト	0.91	実用上問題となる損傷の発生なし（0.95回：微小き裂発生）
	C	0.90	0.59	0.65	0.07	0.0040	Cr:0.29	5	531	408	375	33	表：パーライト 内：パーライト	0.86	実用上問題となる損傷の発生なし（0.82回：微小き裂発生）
	D	0.91	0.60	0.65	0.07	0.0086	Cr:0.28	5	535	409	389	20	表：パーライト 内：パーライト	0.85	実用上問題となる損傷の発生なし（0.92回：微小き裂発生）
	E	0.90	0.58	0.64	0.07	0.0151	Cr:0.28	5	532	410	398	12	表：パーライト 内：パーライト	0.85	損傷発生なし（1.00回）
	F	0.96	0.82	0.85	0.05	0.0045		4	512	405	370	35	表：パーライト 内：パーライト	0.82	実用上問題となる損傷の発生なし（0.79回：微小き裂発生）
	G	0.96	0.81	0.85	0.05	0.0175		4	515	407	396	11	表：パーライト 内：パーライト	0.81	損傷発生なし（1.00回）
	H	0.97	0.72	0.50	0.02	0.0064	Nb:0.012	8	584	425	395	30	表：パーライト 内：パーライト	0.67	実用上問題となる損傷の発生なし（0.65回：微小き裂発生）
	I	0.97	0.98	0.35	0.04	0.0040	Ca:0.0022	10	567	435	400	35	表：パーライト 内：パーライト	0.64	実用上問題となる損傷の発生なし（0.87回：微小き裂発生）
	J	1.04	0.45	0.55	0.12	0.0352	Ti:0.0054	1	454	372	360	12	表：パーライト 内：パーライト	0.69	損傷発生なし（1.00回）
	K	1.11	0.61	0.15	0.17	0.0032	Cu:0.15	9	575	438	405	33	表：パーライト 内：パーライト	0.40	実用上問題となる損傷の発生なし（0.92回：微小き裂発生）
	L	1.20	0.15	0.55	0.10	0.0221	Mo:0.03	15	625	459	430	29	表：パーライト 内：パーライト	0.17	損傷発生なし（1.00回）

注；残部は不可避的不純物およびFe。

[0046] Moreover, the chemical entity, the head accelerated cooling conditions, the rail head axial center section hardness, and the head microstructure of comparison rail steel are shown in Table 2. Moreover, the rolling fatigue test result shown in the abrasion loss after the 700,000 times repetition by Nishihara style abrasion test under the forced-cooling conditions shown in Table 1 at drawing 2 and drawing 3 was also written together.

[0047]

[Table 2]

レール	符号	化学成分 (mass%) C	Si	Mn	V	N	Cr/Mo/Cu/Ni/Nb Ti/Mg/Ca/Co	頭部加速冷却条件 冷却速度 (℃/sec)	停止温度 (℃)	頭部軸心部硬さ (Hv 10kgf) 頭表部 (1mm点)	頭部内部 (20mm点)	硬度差	頭部ミクロ組織 表：頭表部1mm点 内：頭部内部20mm点	頭部材料摩耗量 (g)	転動疲労試験結果 内部疲労損傷発生の有無 (×10⁷)
比較レール鋼	M	0.80	0.60	1.09	—	—	Cr:0.25	4	530	401	360	41	表：パーライト 内：パーライト	1.18 摩耗大	硬度差大 損傷発生 (0.74回)
	N	0.80	0.35	1.05	—	—	Cr:0.21	3	541	390	349	41	表：パーライト 内：パーライト	1.22 摩耗大	硬度差大 損傷発生 (0.38回)
	O	0.82	0.80	0.78	—	—	Cr:0.55	4	562	426	380	46	表：パーライト 内：パーライト	1.10 摩耗大	硬度差大 損傷発生 (0.84回)
	P	1.51	0.62	0.62	0.04	0.0088		8	505	446	420	26	内：パーライト+セメンタイト 内：パーライト+セメンタイト	0.16	セメンタイト生成 損傷発生 (0.89回)
	Q	0.92	0.62	1.78	0.03	0.0102		6	468	589	420	169	表：パーライト+マルテンサイト 内：パーライト	3.21 摩耗大	硬度差大 損傷発生 (0.57回)
	R	0.91	0.61	0.64	0.005	0.0120	Cr:0.25	5	562	410	365	45	表：パーライト 内：パーライト	0.89	硬度差大 損傷発生 (0.61回)
	S	0.90	0.62	0.60	0.002	0.0152	Cr:0.22	8	572	425	377	48	表：パーライト 内：パーライト	0.75	硬度差大 損傷発生 (0.62回)
	T	1.15	0.45	0.51	0.08	0.0121		0.5	564	375	355	20	表：パーライト+セメンタイト 内：パーライト+セメンタイト	0.59	セメンタイト生成 損傷発生 (0.61回)
	U	0.91	0.62	0.61	0.07	0.0152	Cr:0.22	20	482	442	498	56	表：パーライト+ベイナイト 内：パーライト+マルテンサイト	2.45 摩耗大	マルテンサイト生成 損傷発生 (0.34回)
	V	0.91	0.65	0.61	0.07	0.0089	Cr:0.24	5	701	342	321	21	表：パーライト 内：パーライト	1.18 摩耗大	硬度小 損傷発生 (0.25回)
	W	0.92	0.62	0.64	0.06	0.0120		10	402	424	489	65	表：パーライト 内：パーライト+マルテンサイト	0.78	マルテンサイト生成 損傷発生 (0.40回)

注；残部は不可避的不純物およびFe。

[0048] Drawing 4 compares the abrasion test result of the comparison rail steel (eutectoid carbon content steel) shown in this invention rail steel shown in Table 1, and Table 2 with the relation between hardness and abrasion loss. Drawing 5 , and 6 and 7 are examples of head cross-section degree-of-hardness distribution of this invention rail steel (Sign C, Sign D, Sign

E). Moreover, drawing 8 and 9 are examples of head cross-section degree-of-hardness distribution of comparison rail steel (Sign R, Sign S).
[0049] As for a rail test piece and 4, in drawing 2 , 3 is [partner material and 5] the nozzles for cooling. Moreover, in drawing 3 , 6 is a slider for rail migration and a rail 7 is installed on this. 10 is load load equipment which controls the motion and load of right and left of a wheel 8 which are rotated by the motor 9. A wheel 8 rolls a trial on the rail 7 which moves to right and left.
[0050] In addition, the configuration of a rail is as follows.
- This invention rail steel (12) Pearlite system rail which was excellent in the abrasion resistance and the interior fatigue damage nature of -proof which are characterized by for the range of 20mm depth presenting a pearlite organization for this head front face as an origin from a rail head front face at least, and for the hardness of the pearlite organization of said range being 360 or more Hv(s), and the difference of the hardness being [of this steel rail] 40 or less Hv in the sign A-L above-mentioned component range.
- Comparison rail steel (11)
Sign M-O: Comparison rail steel according [a chemical entity] to the eutectoid carbon content steel besides the above-mentioned generic claim (3).
Sign P-S: Comparison rail steel according [a chemical entity] to the hyper-eutectoid carbon content steel besides the above-mentioned generic claim (4).
Sign T-W: Comparison rail steel according [manufacture conditions] to the hyper-eutectoid carbon content steel besides the above-mentioned generic claim (4).
[0051] Abrasion test conditions were carried out as follows.
testing machine : -- Nishihara style abrasion tester test piece configuration: -- disc-like test piece (outer diameter: 30mm, thickness:8mm)
Test load :686-N slip ratio : 20% partner material : Pearlite steel (Hv390)
Ambient atmosphere : cooling among atmospheric air : Forced cooling by the compressed air (flow rate: 100 Nl/min)
Repeat count: 700,000 times [0052] The conditions of a rolling fatigue test were carried out as follows.
testing-machine: -- rolling fatigue tester test piece configuration rail: -- 136pound rail x2m vehicle ring: -- AAR type (diameter of 920mm)
Radial road: 147000-N thrust loading: 9800-N lubrication : Dry cleaning + oil (intermittent oil supply)
[0053] As shown in drawing 5 , by raising a carbon content compared with comparison rail steel, this invention rail steel has little abrasion loss in the same hardness, and its abrasion resistance is improving greatly.
[0054] As shown in drawing 6 , by dedicating the addition of V to the suitable range, compared with drawing 9 and the comparison rail steel (Sign R, Sign S) shown in 10, the hardness difference of a rail head front face and the interior can decrease, and this invention rail steel (sign C) can prevent generating of internal fatigue damage, as shown in Table 1.
[0055] Moreover, by adding N in addition to V, as this invention rail steel (sign D) is shown in drawing 7 , compared with this invention rail steel (sign C), the hardness difference of a rail front face and the interior decreases.
[0056] Furthermore, by controlling the addition of N in 0.0100 - 0.0200% of range, as shown in drawing 8 , compared with this invention rail steel (sign C), the hardness difference of a rail front face and the interior decreases, and the interior fatigue damage nature of -proof of this invention rail steel (sign E) improves further compared with this invention rail steel (sign C).
[0057] It becomes possible to make the pearlite organization of a high degree of hardness generate stably to the interior of a rail head, without a free cementite organization harmful to the toughness of a rail or abrasion resistance and martensitic structure making it generate by

dedicating a chemical entity to the suitable range, as shown in Tables 1 and 2, and choosing suitable heat treatment conditions.
[0058]
[Effect of the Invention] Thus, according to this invention, a heavy loading railroad can be provided with the rail excellent in abrasion resistance and the interior fatigue damage nature of -proof.

[Translation done.]

TECHNICAL FIELD

[Field of the Invention] This invention relates to the pearlite system rail which raised the abrasion resistance and the interior fatigue damage nature of -proof which are required of the rail of a heavy loading railroad, and its manufacturing method.

[Translation done.]

* NOTICES *

PRIOR ART

[Description of the Prior Art] On the overseas heavy loading railroad, improvement in a train rate and train loading weight increase are planned as a means of efficient-izing of railroad transportation. Much more improvement of the rail quality of the material has come [the increase in efficiency of such railroad transportation meant severe-ization of a rail operating environment, and] to be required. By the rail laid at the curvilinear section, wear of the G.C. (gage corner) section or a head flank increases rapidly, and, specifically, came to be regarded as questionable in respect of the use life of a rail.
[0003] However, the high intensity (high degree of hardness) rail as shown in the following which presented the fine pearlite organization using eutectoid carbon steel by advance of the latest high intensity-ized heat treatment technique was invented, and the rail life of the curvilinear section of a heavy loading railroad has been improved by leaps and bounds.
** The heat-treated rail for super-****** of sorbite or a detailed pearlite organization in a head (JP,54-25490,B).
** The manufacturing method of two or more 130 kgf(s)/mm high intensity rails which carry out accelerated cooling of for 850-500 degrees C after rolling termination or for the rail head which reheated by 1-4 degrees C/sec from austenite region temperature (patent No. 1597914).
The description of these rails was a high intensity rail which presents the fine pearlite organization by eutectoid carbon content steel (carbon content: 0.7 - 0.8%), and the place made into the purpose made lamellae spacing under pearlite organization detailed, and suited at the place which raises abrasion resistance.
[0004] However, high loading-ization of a cargo is powerfully advanced for efficient-izing of much more railroad transportation, and by the rail of a sudden curve, even if it uses the rail of the above-mentioned development, the abrasion resistance of the G.C. section or a head flank cannot secure enough, but the fall of the rail life by wear has posed a problem especially on the overseas heavy loading railroad in recent years. From such a background, development of the rail which has the abrasion resistance more than the high intensity rail of the present eutectoid carbon steel has come to be called for.
[0005] In order to solve these problems, this invention persons developed the rail as shown below.
** The rail which was excellent in the abrasion resistance to which the cementite consistency in the lamellae under pearlite organization was made to increase using hypereutectoid steel (C:0.85 ** -1.20%) (JP,8-144061,A official report)
** The rail excellent in the abrasion resistance which was made to increase the cementite consistency in the lamellae under pearlite organization, and controlled hardness to coincidence using hypereutectoid steel (C:0.85 ** -1.20%) (JP,8-246100,A official report)
The description of these rails was what increases the carbon content of steel, is made to increase the consistency of the cementite phase excellent in the abrasion resistance in pearlite lamellae, and raises the abrasion resistance of a pearlite organization by controlling hardness

further.
[0006] Furthermore, this invention persons developed the rail as shown in the following which raised the abrasion resistance of a rail head, and the interior fatigue damage nature of -proof using hypereutectoid steel with a high carbon content.
** The rail which raised abrasion resistance and the interior fatigue damage nature of -proof by adding B to hypereutectoid steel (C:0.85 ** -1.20%) (Japanese-Patent-Application-No. No. 527465 [eight to] official report).
the description of this rail promotes a pearlite transformation by adding minute amount B to hypereutectoid steel -- making -- the more uniform degree-of-hardness distribution from a rail head front face to the interior -- giving -- the abrasion resistance of a rail, and the interior fatigue damage nature of -proof -- it was what is raised greatly.

[Translation done.]

EFFECT OF THE INVENTION

[Effect of the Invention] Thus, according to this invention, a heavy loading railroad can be provided with the rail excellent in abrasion resistance and the interior fatigue damage nature of -proof.

[Translation done.]

* NOTICES *

TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention] Although it is expected that the invention rail shown in the above-mentioned ** has abrasion resistance and the interior fatigue damage nature of -proof by adding minute amount B to hypereutectoid steel (C:0.85 ** -1.20%) excellent in abrasion resistance, and contributes them to high life-ization of the rail for heavy loading railroads most Depending on the difference in the component system of steel, it only added and ordered B to hypereutectoid steel, and it became clear then that the facilitatory effect of a pearlite transformation may not fully be acquired and uniform degree-of-hardness distribution may not be acquired from a rail head front face to the interior.
[0008] Then, this invention persons examined the alloying element which replaces B by experiment in order to solve this trouble. As a result of conducting the accelerated cooling experiment of the rail head using a real rail, as compared with the heading part, by adding V to hypereutectoid steel, the carbide of V tended to deposit on the ferrite background under par rye flume organization, and it was checked inside the rail head where a cooling rate is slow that the degree of hardness inside a rail head improves.
[0009] Furthermore, this invention persons examined the element which raises the effectiveness of V further by the above-mentioned experiment. consequently, addition of V -- in addition, the carbide of V which deposits on the ferrite background under par rye flume organization of hypereutectoid steel by carrying out compound addition of the N -- in addition, the nitride of V deposited and it was checked that the degree of hardness inside a rail head improves sharply. It checked that this invention persons could enable improvement in a degree of hardness also in the interior of a rail head, and could raise abrasion resistance and the interior fatigue damage nature of -proof from the above experimental result to coincidence V and by adding N in addition to V further instead of addition of B to hypereutectoid steel.
[0010] In addition, this invention persons examined the heat treatment conditions for attaining V and high intensity-ization of the steel rail which added N further in addition to V by experiment. Consequently, in order not to make abnormal structure, such as martensite, generate in a heading part, but to have made the pearlite organization excellent in abrasion resistance generate stably, to have deposited the carbide and the nitride of V in the interior of a rail head in coincidence and to have aimed at improvement in a degree of hardness, it checked that the fixed range existed in the cooling rate of a heading part.
[0011] In order that this invention persons may raise the abrasion resistance of the rail for heavy loading railroads, and the interior fatigue damage nature of -proof, the carbon content of rail steel is made to increase from the above result first. To coincidence to V and a pan By making the carbide and the nitride of V generate stably, in addition performing accelerated cooling heat treatment by adding N in addition to V The knowledge of the ability to manufacture the high intensity rail excellent in abrasion resistance and the interior fatigue damage nature of -proof with high degree-of-hardness distribution uniform from a rail head front face to the interior was carried out.

[0012] That is, the purpose of this invention is related with the pearlite system rail aiming at raising the abrasion resistance required of the rail of a heavy loading railroad, and raising the interior fatigue damage nature of -proof stably to coincidence, and its manufacturing method.

[Translation done.]

* NOTICES *

MEANS

[Means for Solving the Problem] The place which this invention attains the above-mentioned purpose and is made into the summary is as follows.
(1) At mass %, it is C. : 0.85 ** -1.20%, Si: 0.10-1.00%, Mn:0.10-1.50%, V 0.02 - 0.20% is contained and the need is accepted further. : [Cr:0.05-1.00%,] Mo: 0.01-0.20%, Cu:0.05-0.50%, nickel: 0.05-1.00%, Nb:0.002-0.050% Ti:0.0050-0.0300%, Mg: The pearlite system rail excellent in the abrasion resistance and the interior fatigue damage nature of -proof which are characterized by containing one sort (0.0010-0.0100%, calcium:0.0010-0.0150%, and Co:0.10-2.00%) or two sorts or more, and the remainder consisting of Fe and an unescapable impurity.
(2) At mass %, it is C. : 0.85 ** -1.20%, Si: 0.10-1.00%, Mn:0.10-1.50%, V : 0.02 - 0.20%, N : 0.0060 - 0.0500% is contained and the need is accepted further. Cr:0.05-1.00%, Mo: 0.01-0.20%, Cu:0.05-0.50%, nickel: 0.05-1.00%, Nb:0.002-0.050% Ti:0.0050-0.0300%, Mg: The pearlite system rail excellent in the abrasion resistance and the interior fatigue damage nature of -proof which are characterized by containing one sort (0.0010-0.0100%, calcium:0.0010-0.0150%, and Co:0.10-2.00%) or two sorts or more, and the remainder consisting of Fe and an unescapable impurity.
(3) the pearlite system rail excellent in the abrasion resistance and the interior fatigue damage nature of -proof which be characterize by consider as the pearlite organization whose range of 20mm depth be the rail which have a component the above (1) or given in (2), and be the range of hardness 360-Hv 480 at least considering the head corner section and the parietal region front face of said steel rail as an origin and, whose difference of the hardness be 40 or less Hv.
(4) The steel rail head of the temperature of one or more Ar(s) of a hot rolling as which consists of a component the above (1) or given in (2), Or the steel rail head heated by one Ac temperature of +30 degrees C or more in order to heat-treat Carry out accelerated cooling with the cooling rate of 1-15 degrees C/sec from austenite region temperature, when the temperature of the head of said steel rail attains 650-450 degrees C, stop accelerated cooling, and it cools radiationally after that. The range of 20mm depth at least the head corner section and the parietal region front face of said steel rail as an origin in the range of hardness 360-Hv 480 And the manufacture approach of a pearlite system rail excellent in the abrasion resistance and the interior fatigue damage nature of -proof which are characterized by considering as the pearlite organization whose difference of the hardness is 40 or less Hv.
[0014]
[The mode of implementation of invention] Hereafter, this invention is explained to a detail. In claims 1-12, the reason which limited the difference of the range of a chemical entity or a chemical entity, and a pearlite organization, hardness, and the hardness of a pearlite organization like the above-mentioned generic claim is explained to a detail.
[0015] (1) a part for ****** of rail steel -- explain first the reason which limited the chemical entity of a rail as mentioned above in this invention. Although it is the effective element which

C makes promote a pearlite transformation and secures abrasion resistance and the 0.60 - 0.85% of the amounts of C is added as usual rail steel, at the 0.85% or less of the amounts of C, the consistency of the cementite phase under pearlite organization for aim at wear-resistant improvement is not securable, further, it becomes easy to generate the grain boundary ferrite used as the origin of fatigue damage, and a rail life falls to the interior of a rail head. Moreover, when the amount of C exceeded 1.20%, depending on the component system, the free cementite organization generated during the pearlite organization, the consistency of that the toughness of a rail and ductility fall greatly and the cementite phase under pearlite organization increased, and since it became impossible to fully secure the ductility needed for a rail, the amount of C was limited to 0.85 ** -1.20%.
[0016] Although Si was an element which raises the degree of hardness (reinforcement) of a rail head by solid-solution hardening to the ferrite phase under pearlite organization, if the effectiveness was not fully able to expect and exceeded 1.00%, since weldability would fall by that many surface cracks generate at the time of hot rolling, and generation of an oxide, it limited the amount of Si to 0.10 - 1.00% at less than 0.10%.
[0017] Mn reduces the pearlite temperature of transformation and contributes to high intensity-ization by raising hardenability, further, although it is an element which controls generation of a free cementite organization, with less than 0.10% of content, the effectiveness is small and it becomes difficult to secure [of the hardness needed for a rail head] it. Moreover, if it exceeded 1.50%, since hardenability would increase remarkably, becoming easy to generate martensitic structure and a segregation would be promoted and it would become easy to generate a free cementite organization harmful to the toughness of a rail in the segregation section, the amount of Mn was limited to 0.10 - 1.50%.
[0018] Although it is the element which raises the degree of hardness inside a head by V's forming carbide and a nitride in heat treatment of a rail head inside the rail head where a cooling rate is slow as compared with a heading part, and depositing on the ferrite background under pearlite organization, at less than 0.01%, formation of a nitride or a nitride becomes difficult and precipitation hardening of the pearlite organization inside a rail head becomes difficult. Moreover, the addition of N in which the effectiveness beyond it not being expectable even if it adds exceeding 0.20%, and the nitride of V are made to form and which is the equivalent chemically exceeded 0.0500%, and since it became easy to generate the internal defect of the blowhole which serves as an origin of internal fatigue damage at the time of a molten steel ingot, the amount of V was limited to 0.01 - 0.20%.
[0019] Furthermore, since N is made to contain and the effectiveness of V may be heightened by the synergistic effect, it adds if needed. Although it is the element which raises further the degree of hardness inside the comparatively late rail head of a cooling rate by N's combining with V, forming the nitride of V, and depositing on the ferrite background under pearlite organization, at less than 0.0060%, generation of the nitride of V becomes difficult. Moreover, if it exceeded 0.0500%, since it would become easy to generate the internal defect of the blowhole which serves as an origin of internal fatigue damage at the time of a molten steel ingot, the amount of N was limited to 0.0060 - 0.0500%. In addition, in order to aim at the rise of the hardness inside a rail, to make the nitride of V generate stably and to control generating of the internal defect of a blowhole etc. to coincidence, it is desirable to make N addition into 0.0100 - 0.0200% of range.
[0020] Moreover, the rails manufactured by the above-mentioned component presentation are reinforcement, ductility, toughness, and the purpose that prevents ingredient degradation at the time of welding further, and add one kind or two sorts or more for the element of Cr, Mo, Cu, nickel, Nb, Ti, Mg, calcium, and Co if needed. here -- in high-intensity-izing, wear-resistant improvement, and nickel, Nb and Ti, ductility, toughness simultaneously reinforcement, improvement, and Cu and Co add Mg, and the improvement in on the strength and calcium

add [Cr and Mo] improvement in ductility and toughness as main purposes.
[0021] Although it is the element which raises abrasion resistance by strengthening the cementite phase under pearlite organization at the same time Cr raises the balanced transformation point of a pearlite, it makes a pearlite organization detailed as a result and it contributes to high intensity-ization At less than 0.05%, the effectiveness was small, and if superfluous addition exceeding 1.00% was performed, in order that martensitic structure might generate so much and might reduce the toughness of a rail, the amount of Cr(s) was limited to 0.05 - 1.00%.
[0022] Although it is the element which Mo raises the balanced transformation point of a pearlite like Cr, contributes to high intensity-ization by making a pearlite organization detailed as a result, and raises abrasion resistance The effectiveness was small, and at less than 0.01%, when superfluous addition exceeding 0.20% was performed, the segregation was promoted, and since a pearlite transformation rate fell, martensitic structure generated in the segregation section and the toughness of a rail fell, the amount of Mo was further limited to 0.01 - 0.20%.
[0023] Cu was an element which does not spoil the toughness of pearlite steel but raises reinforcement, and if the effectiveness was the largest in 0.05 - 0.50% of range and it exceeded 0.50%, since it would become easy to produce red-heat embrittlement, it limited the amount of Cu(s) to 0.05 - 0.50%.
[0024] Although it is the element which nickel raises the ductility of pearlite steel, and toughness and attains high intensity-ization of pearlite steel by solid solution strengthening to coincidence, at less than 0.05%, the effectiveness is remarkably small, and even if it performs superfluous addition exceeding 1.00%, effectiveness beyond it is not expectable. Therefore, the amount of nickel was limited to 0.05 - 1.00%.
[0025] Nb raises reinforcement by precipitation hardening by Nb carbide and Nb nitride like V, in case heat treatment heated to high temperature is performed further, an austenite grain is made to make it detailed according to the operation which controls grain growth, and rather than V, the austenite grain growth suppression effectiveness acts to a high temperature region (about 1200 degrees C), and improves the ductility of a pearlite organization, and toughness. At less than 0.002%, even if the effectiveness performs superfluous addition which cannot expect and exceeds 0.050%, it cannot expect effectiveness beyond it. Therefore, the amount of Nb(s) was limited to 0.002 - 0.050%.
[0026] Ti is a component effective in attaining detailed-ization of the austenite crystal grain at the time of rolling heating, and raising the ductility and the toughness of a pearlite organization using depositing Ti carbide and Ti nitride not dissolving, in reheating of rail pressure Nobutoki. However, at less than 0.0050%, if there is little the effectiveness and it adds exceeding 0.0300%, in order for big and rough Ti carbide and Ti nitride to generate, and for the origin of fatigue damage rail in use to come and to generate a crack, the amount of Ti was limited to 0.0050 - 0.0300%.
[0027] Mg is an element effective in combining with O or S, aluminum, etc., forming a detailed oxide, controlling grain growth of crystal grain in reheating of rail pressure Nobutoki, attaining detailed-ization of an austenite grain, and raising the ductility and the toughness of a pearlite organization. Furthermore, it is an element effective in raising the ductility and the toughness of a pearlite organization by MgO and MgS distributing MnS minutely, forming the thin band of Mn in the perimeter of MnS, and contributing to generation of a pearlite transformation, consequently making a pearlite block size detailed. However, at less than 0.0010%, if it was weak and added exceeding 0.0100%, in order that the big and rough oxide of Mg might generate the effectiveness and it might degrade rail ductility and toughness, it limited the amount of Mg to 0.0010 - 0.0100%.
[0028] calcium is an element effective in raising the ductility and the toughness of a pearlite

organization by bonding strength with S being strong and forming a sulfide as CaS, and CaS's distributing MnS minutely, forming the thin band of Mn in the perimeter of MnS further, and contributing to generation of a pearlite transformation, consequently making a pearlite block size detailed. However, at less than 0.0010%, if it was weak and added exceeding 0.0150%, in order that the big and rough oxide of calcium might generate the effectiveness and it might degrade rail ductility and toughness, it limited the amount of calcium to 0.0010 - 0.0150%.
[0029] Although Co was an element which raises reinforcement by making the transformation energy of a pearlite increase and making a pearlite organization detailed, since the effectiveness arrived at a saturation region even if it performs superfluous addition which cannot expect the effectiveness and exceeds 2.00%, it limited the amount of Co(es) to 0.10 - 2.00% at less than 0.10%.
[0030] The rail steel which consists of above component presentations ingots with fusion furnaces usually used, such as a converter and an electric furnace, and ingot making and a cogging method or a continuous casting process, and a pan manufacture this molten steel as a rail through hot rolling. Next, it becomes possible to make a rail head generate stably the pearlite organization where hardness is high by heat-treating on the rail head reheated by the elevated temperature for the rail which holds the heat of this hot-rolled high temperature, or the purpose to heat-treat.
[0031] (2) Explain the reason which limited the desirable hardness of a pearlite organization to the range of Hv 360-480 at the beginning of the desirable hardness of a pearlite organization, and its range. If hardness is set to less than 360 Hv by this component system, wear of a rail will advance, it will become difficult to secure the abrasion resistance demanded on the heavy loading railroad, and it will further become easy to generate a fatigue crack from the interior of a head by the rail used in the sudden curvilinear section. moreover, the thing which concordance nature with the wheel of a heading part will fall, and will be become easy to generate a surface damage if hardness exceeds Hv480 – moreover, in rail heat treatment manufacture, in order for abnormal structure, such as bainite and martensite, to generate on a rail head and to reduce the abrasion resistance of a rail, and the interior fatigue damage nature of -proof on it, hardness was limited to the range of Hv 360-480.
[0032] Next, the reason which limited this head front face of the head corner section and the parietal region for the desirable range which the pearlite organization of the range of hardness 360-Hv 480 presents to the range of 20mm depth as an origin is explained. In less than 20mm, as the abrasion resistance needed for the rail head, and an interior fatigue damage nature field of -proof, it is small, and is because sufficient life improvement effect is not acquired according to advance of wear, and generating of internal fatigue damage. Moreover, if there is range which presents said pearlite organization a depth of 30mm or more considering this head front face of the head corner section and the parietal region as an origin, a life improvement effect increases further and is more desirable.
[0033] Here, the field by which the name and abrasion resistance in the head cross-section surface location of the rail excellent in the abrasion resistance of this invention and the interior fatigue damage nature of -proof are needed for drawing 1 is shown. In a rail head, 1 is the parietal region, 2 is the head corner section, and one side of the head corner section 2 is the gage corner (G. C.) section which mainly contacts a wheel. Moreover, if the pearlite organization of the range of hardness 360-Hv 480 is stationed at least in the shadow area in drawing, improvement in a rail use life of it will be attained.
[0034] (3) Explain to the difference last of the desirable hardness of a pearlite organization the reason which limited the maximum of the difference of the hardness of a desirable pearlite organization in the range of 20mm depth to 40 or less Hv. In a rail head, since a cooling rate changes at least with each part of a cross section, generally hardness shows the distribution which falls as it goes to the interior of a head from a heading part. If the hardness difference

inside this rail head front face and a head exceeds Hv40, change of material strength will become remarkably large in a rail head cross section. Since distortion (plastic deformation field) generated from the external force which acts on a rail concentrated on the low degree-of-hardness (reinforcement) section inside a rail head in connection with this, consequently internal fatigue damage occurred and a rail life fell, the maximum of the difference of hardness was limited to 40 or less Hv.
[0035] (4) Explain to a detail the reason which limited heating at the time of rail manufacture, and cooling conditions as mentioned above in the manufacture approach of manufacture condition this invention. First, in order to obtain a predetermined organization and a predetermined degree of hardness, it is necessary to make a rail head fully austenitize at least, although it is the temperature conditions before cooling a rail head. In the rail head which is the temperature region of one or more Ar(s) in the rail head immediately after rolling, and was reheated, one Ac temperature of +30 degrees C or more is required for the temperature. In addition, although especially the upper limit of temperature is not specified, since the liquid phase will appear and an austenite phase will become unstable if it is made high temperature not much, as for temperature, 1350 degrees C of parenchyma serve as an upper limit.
[0036] It is the part which contains the rail parietal region (sign: 1) indicated to be the above-mentioned "rail head" to drawing 1 , and the head corner section (sign: 2) here. The range of 20mm depth (shadow area of drawing 2) can be represented at least, and the cooling rate and temperature which are explained below will become possible [the thing of a rail head for which the organization and degree of hardness of said part (shadow area of drawing 2) are controlled at least], if the depth measures in the range which is 2-5mm from the head front face of the rail parietal region (sign: 1) shown in said drawing 2 , and the head corner section (sign: 2).
[0037] Next, in the approach of carrying out accelerated cooling of the between from austenite region temperature to 650-450 degrees C for a rail head with the cooling rate of 1-15 degrees C/sec, the reason which limited accelerated cooling halt temperature as mentioned above is explained. If accelerated cooling was stopped at the temperature exceeding 650 degrees C, since a pearlite transformation began immediately after accelerated cooling, the pearlite organization where hardness is low generated mostly, the hardness of a rail head was set to less than 360 Hv and neither abrasion resistance nor the interior fatigue damage nature of -proof was able to be secured, it limited to 650 degrees C or less. Moreover, when accelerated cooling was performed to less than 450 degrees C, sufficient recuperation from the interior of a rail was not expectable after accelerated cooling, and in order that martensitic structure harmful to the toughness of a rail and the interior fatigue damage nature of -proof might generate in the segregation section inside a rail head etc., it limited to 450 degrees C or more.
[0038] Moreover, if the accelerated cooling rate of a rail head becomes under 1 degree C / sec, a pearlite transformation will begin in the high temperature region in the middle of accelerated cooling. The pearlite organization where hardness is low generates mostly, and the hardness of a rail head is set to less than 360 Hv. That reservation of the abrasion resistance of a rail head and the interior fatigue damage nature of -proof becomes difficult, and in order that a free cementite organization harmful to the toughness of a rail and ductility might generate depending on a component system, it limited 1 degree C / more than sec. If an accelerated cooling rate exceeds 15 degrees C/sec, in order for abnormal structure, such as bainite and a marte site, to generate on a rail head and to reduce abrasion resistance and the interior fatigue damage nature of -proof into accelerated cooling, without carrying out a pearlite transformation, the accelerated cooling rate was limited to the range of 1-15 degrees C/sec. In addition, in order to make the pearlite organization where a degree of hardness is high generate stably to the interior of a rail head, it is most desirable to make an accelerated cooling rate into the range of 5-10 degrees C/sec.

[0039] Although this accelerated cooling speed range limits the average cooling rate from cooling initiation to termination, a temporary temperature rise by generation of heat by pearlite transformation or the natural recuperation from the interior of a rail may occur [in the middle of accelerated cooling]. However, if the average cooling rate from accelerated cooling initiation to termination is above-mentioned within the limits, since there is ****** about the big effect in the property of this pearlite system rail, it also includes the fall of the cooling rate accompanying a temporary temperature rise in the middle of cooling as accelerated cooling conditions for this rail. [no]
[0040] Moreover, it is possible to obtain a predetermined cooling rate with the cooling media which were mainly concerned with air or air and added Myst etc. as an approach of obtaining the cooling rate of 1-15 degrees C/sec, and such combination.
[0041] Therefore, in order to manufacture the rail excellent in the abrasion resistance and the interior fatigue damage nature of -proof which presented the 360 or more-Hv pearlite organization So that generation of the pearlite organization where hardness is low may be prevented and free cementite harmful to abrasion resistance, ductility, toughness, and the interior fatigue damage nature of -proof, martensite, and a bainite texture may not generate in a heading part By stopping accelerated cooling, when accelerated cooling is carried out with the cooling rate of 1-15 degrees C/sec from austenite region temperature using the refrigerant which was mainly concerned with air or air and added Myst etc. and the temperature of this steel heading part attains 650-450 degrees C It becomes possible to make the pearlite organization of a high degree of hardness generate stably from a heading part to the interior.
[0042] Radiationnal cooling, i.e., cool naturally, is desirable until it does not perform cooling with compulsory <the explanation important point of subsequent radiationnal cooling> and cooling after accelerated cooling but completes a pearlite transformation. in addition, a production disposition -- cooling, after a pearlite transformation completes in order to prevent generation of the organization which reduces the toughness of rails, such as martensitic structure, when cooling a rail compulsorily, since it is good -- ** -- better. In addition, in this component system, the temperature which the pearlite transformation of the whole rail head completes mostly is in the condition that the temperature of a rail head front face was cooled by less than 350 degrees C.
[0043] Although it is desirable that he is a pearlite organization as a metal texture of a rail, depending on a component system, an accelerated cooling rate, and the segregation condition of a material, a minute amount proeutectoid ferrite organization and a free cementite organization may generate during a pearlite organization. However, even if these organizations generate during a pearlite organization at a minute amount, since there is nothing ****** about the big effect about the abrasion resistance, the ductility, the toughness, the interior fatigue damage nature of -proof, and reinforcement of a rail, as an organization of this pearlite system rail, mixture of some proeutectoid ferrite organization and a free cementite organization is also included.

[Translation done.]

EXAMPLE

[Example] Next, the example of this invention is explained. The chemical entity, the head accelerated cooling conditions, the rail head axial center section hardness, and the head microstructure of this invention rail steel are shown in Table 1. Moreover, the rolling fatigue test result shown in the abrasion loss after the 700,000 times repetition by Nishihara style abrasion test under the forced-cooling conditions shown in Table 1 at drawing 2 and drawing 3 was also written together.
[0045]
[Table 1]

レール	符号	化学成分 (mass%) C	Si	Mn	V	N	Cr/Mo/Cu/Ni/Nb Ti/Mg/Ca/Co	頭部加速冷却条件 冷却速度 (℃/sec)	停止温度 (℃)	頭部軸心部硬さ (Hv 10kgf) 頭表部 (1mm点)	頭部内部 (20mm点)	硬度差	頭部ミクロ組織 表；頭表部 1mm点 内；頭部内部20mm点	頭部材料摩耗量 (g)	転動疲労試験結果 内部疲労損傷発生の有無 (×10^7)
本発明レール鋼	A	0.85	0.61	1.38	0.05	0.0039	Mg:0.0017	5	520	414	384	30	表：パーライト 内：パーライト	0.96	実用上問題となる損傷の発生なし (0.85回：微小き裂発生)
	B	0.87	0.45	1.25	0.08	0.0087	Co:0.22	4	556	400	378	22	表：パーライト 内：パーライト	0.91	実用上問題となる損傷の発生なし (0.95回：微小き裂発生)
	C	0.90	0.59	0.65	0.07	0.0040	Cr:0.29	5	531	408	375	33	表：パーライト 内：パーライト	0.86	実用上問題となる損傷の発生なし (0.82回：微小き裂発生)
	D	0.91	0.60	0.65	0.07	0.0086	Cr:0.28	5	535	409	389	20	表：パーライト 内：パーライト	0.85	実用上問題となる損傷の発生なし (0.92回：微小き裂発生)
	E	0.90	0.58	0.64	0.07	0.0151	Cr:0.28	5	532	410	398	12	表：パーライト 内：パーライト	0.85	損傷発生なし (1.00回)
	F	0.96	0.82	0.85	0.05	0.0045		4	512	405	370	35	表：パーライト 内：パーライト	0.82	実用上問題となる損傷の発生なし (0.79回：微小き裂発生)
	G	0.96	0.81	0.85	0.05	0.0175		4	515	407	396	11	表：パーライト 内：パーライト	0.81	損傷発生なし (1.00回)
	H	0.97	0.72	0.50	0.02	0.0064	Nb:0.012	8	584	425	395	30	表：パーライト 内：パーライト	0.67	実用上問題となる損傷の発生なし (0.85回：微小き裂発生)
	I	0.97	0.98	0.35	0.04	0.0040	Ca:0.0022	10	567	435	400	35	表：パーライト 内：パーライト	0.64	実用上問題となる損傷の発生なし (0.87回：微小き裂発生)
	J	1.04	0.45	0.55	0.12	0.0352	Ti:0.0054	1	454	372	360	12	表：パーライト 内：パーライト	0.69	損傷発生なし (1.00回)
	K	1.11	0.61	0.15	0.17	0.0032	Cu:0.15	9	575	438	405	33	表：パーライト 内：パーライト	0.40	実用上問題となる損傷の発生なし (0.92回：微小き裂発生)
	L	1.20	0.15	0.55	0.10	0.0221	Mo:0.03	15	625	459	430	29	表：パーライト 内：パーライト	0.17	損傷発生なし (1.00回)

注；残部は不可避的不純物およびFe。

[0046] Moreover, the chemical entity, the head accelerated cooling conditions, the rail head axial center section hardness, and the head microstructure of comparison rail steel are shown in Table 2. Moreover, the rolling fatigue test result shown in the abrasion loss after the 700,000 times repetition by Nishihara style abrasion test under the forced-cooling conditions shown in Table 1 at drawing 2 and drawing 3 was also written together.

[0047]

[Table 2]

レール	符号	化学成分 (mass%) C	Si	Mn	V	N	Cr/Mo/Cu/Ni/Nb Ti/Mg/Ca/Co	頭部加速冷却条件 冷却速度 (℃/sec)	停止温度 (℃)	頭部軸心部硬さ (Hv 10kgf) 頭表部 (1 mm点)	頭部内部 (20mm点)	硬度差	頭部ミクロ組織 表：頭表部 1mm点 内：頭部内部20mm点	頭部材料摩耗量 (g)	転動疲労試験結果 内部疲労損傷発生の有無 (×10⁷)
比較レール鋼	M	0.80	0.60	1.09	—	—	Cr:0.25	4	530	401	360	41	表：パーライト 内：パーライト	1.18 摩耗大	硬度差大 損傷発生 (0.74回)
	N	0.80	0.35	1.05	—	—	Cr:0.21	3	541	390	348	41	表：パーライト 内：パーライト	1.22 摩耗大	硬度差大 損傷発生 (0.38回)
	O	0.82	0.30	0.78	—	—	Cr:0.55	4	562	426	380	46	表：パーライト 内：パーライト	1.10 摩耗大	硬度差大 損傷発生 (0.84回)
	P	1.51	0.62	0.62	0.04	0.0088		8	505	446	420	28	内：パーライト+セメンタイト 内：パーライト+セメンタイト	0.16	セメンタイト生成 損傷発生 (0.89回)
	Q	0.92	0.62	1.78	0.03	0.0102		6	468	589	420	169	表：パーライト+マルテンサイト 内：パーライト	3.21 摩耗大	硬度差大 損傷発生 (0.57回)
	R	0.91	0.61	0.64	0.005	0.0120	Cr:0.25	5	562	410	365	45	表：パーライト 内：パーライト	0.69	硬度差大 損傷発生 (0.61回)
	S	0.90	0.62	0.60	0.002	0.0152	Cr:0.22	8	572	425	377	48	表：パーライト 内：パーライト	0.75	硬度差大 損傷発生 (0.62回)
	T	1.15	0.45	0.51	0.08	0.0121		0.5	564	376	355	20	表：パーライト+セメンタイト 内：パーライト+セメンタイト	0.59	セメンタイト生成 損傷発生 (0.61回)
	U	0.91	0.82	0.61	0.07	0.0152	Cr:0.22	20	482	442	498	56	表：パーライト+ベイナイト 内：パーライト+マルテンサイト	2.45 摩耗大	マルテンサイト生成 損傷発生 (0.34回)
	V	0.91	0.65	0.61	0.07	0.0089	Cr:0.24	5	701	342	321	21	表：パーライト 内：パーライト	1.18 摩耗大	硬度小 損傷発生 (0.25回)
	W	0.92	0.62	0.64	0.06	0.0120		10	402	424	489	65	表：パーライト 内：パーライト+マルテンサイト	0.76	マルテンサイト生成 損傷発生 (0.40回)

注；残部は不可避的不純物およびFe。

[0048] Drawing 4 compares the abrasion test result of the comparison rail steel (eutectoid carbon content steel) shown in this invention rail steel shown in Table 1, and Table 2 with the relation between hardness and abrasion loss. Drawing 5 , and 6 and 7 are examples of head cross-section degree-of-hardness distribution of this invention rail steel (Sign C, Sign D, Sign

E). Moreover, drawing 8 and 9 are examples of head cross-section degree-of-hardness distribution of comparison rail steel (Sign R, Sign S).
[0049] As for a rail test piece and 4, in drawing 2 , 3 is [partner material and 5] the nozzles for cooling. Moreover, in drawing 3 , 6 is a slider for rail migration and a rail 7 is installed on this. 10 is load load equipment which controls the motion and load of right and left of a wheel 8 which are rotated by the motor 9. A wheel 8 rolls a trial on the rail 7 which moves to right and left.
[0050] In addition, the configuration of a rail is as follows.
- This invention rail steel (12) Pearlite system rail which was excellent in the abrasion resistance and the interior fatigue damage nature of -proof which are characterized by for the range of 20mm depth presenting a pearlite organization for this head front face as an origin from a rail head front face at least, and for the hardness of the pearlite organization of said range being 360 or more Hv(s), and the difference of the hardness being [of this steel rail] 40 or less Hv in the sign A-L above-mentioned component range.
- Comparison rail steel (11)
Sign M-O: Comparison rail steel according [a chemical entity] to the eutectoid carbon content steel besides the above-mentioned generic claim (3).
Sign P-S: Comparison rail steel according [a chemical entity] to the hyper-eutectoid carbon content steel besides the above-mentioned generic claim (4).
Sign T-W: Comparison rail steel according [manufacture conditions] to the hyper-eutectoid carbon content steel besides the above-mentioned generic claim (4).
[0051] Abrasion test conditions were carried out as follows.
testing machine : -- Nishihara style abrasion tester test piece configuration: -- disc-like test piece (outer diameter: 30mm, thickness:8mm)
Test load :686-N slip ratio : 20% partner material : Pearlite steel (Hv390)
Ambient atmosphere : cooling among atmospheric air : Forced cooling by the compressed air (flow rate: 100 Nl/min)
Repeat count: 700,000 times [0052] The conditions of a rolling fatigue test were carried out as follows.
testing-machine: -- rolling fatigue tester test piece configuration rail: -- 136pound rail x2m vehicle ring: -- AAR type (diameter of 920mm)
Radial road: 147000-N thrust loading: 9800-N lubrication : Dry cleaning + oil (intermittent oil supply)
[0053] As shown in drawing 5 , by raising a carbon content compared with comparison rail steel, this invention rail steel has little abrasion loss in the same hardness, and its abrasion resistance is improving greatly.
[0054] As shown in drawing 6 , by dedicating the addition of V to the suitable range, compared with drawing 9 and the comparison rail steel (Sign R, Sign S) shown in 10, the hardness difference of a rail head front face and the interior can decrease, and this invention rail steel (sign C) can prevent generating of internal fatigue damage, as shown in Table 1.
[0055] Moreover, by adding N in addition to V, as this invention rail steel (sign D) is shown in drawing 7 , compared with this invention rail steel (sign C), the hardness difference of a rail front face and the interior decreases.
[0056] Furthermore, by controlling the addition of N in 0.0100 - 0.0200% of range, as shown in drawing 8 , compared with this invention rail steel (sign C), the hardness difference of a rail front face and the interior decreases, and the interior fatigue damage nature of -proof of this invention rail steel (sign E) improves further compared with this invention rail steel (sign C).
[0057] It becomes possible to make the pearlite organization of a high degree of hardness generate stably to the interior of a rail head, without a free cementite organization harmful to the toughness of a rail or abrasion resistance and martensitic structure making it generate by

dedicating a chemical entity to the suitable range, as shown in Tables 1 and 2, and choosing suitable heat treatment conditions.

[Translation done.]

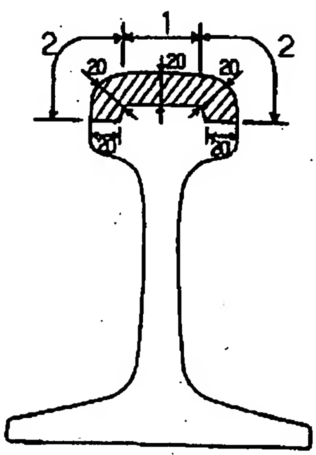
DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] Drawing having shown the name of a rail head cross-section surface location, and the need range of a 370 or more-Hv pearlite organization.
[Drawing 2] The schematic diagram of a Nishihara style abrasion tester.
[Drawing 3] The schematic diagram of a rolling fatigue tester.
[Drawing 4] Drawing which compared the abrasion test result of this invention rail steel and comparison rail steel with the relation between hardness and abrasion loss.
[Drawing 5] Drawing having shown head cross-section degree-of-hardness distribution of this invention rail steel (sign C).
[Drawing 6] Drawing having shown head cross-section degree-of-hardness distribution of this invention rail steel (sign D).
[Drawing 7] Drawing having shown head cross-section degree-of-hardness distribution of this invention rail steel (sign E).
[Drawing 8] Drawing having shown head cross-section degree-of-hardness distribution of comparison rail steel (sign R).
[Drawing 9] Drawing having shown head cross-section degree-of-hardness distribution of comparison rail steel (sign S).
[Brief Description of Notations]
1: Parietal region,
2: Head corner section,
3: Rail test piece,
4: Partner material,
5: The nozzle for cooling,
6: The slider for rail migration,
7: Rail,
8: Wheel,
9: Motor,
10: Load load equipment

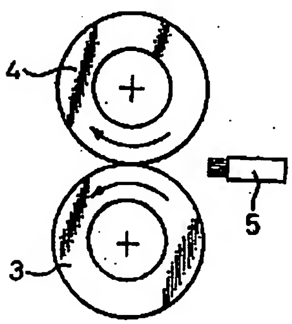
[Translation done.]

DRAWINGS

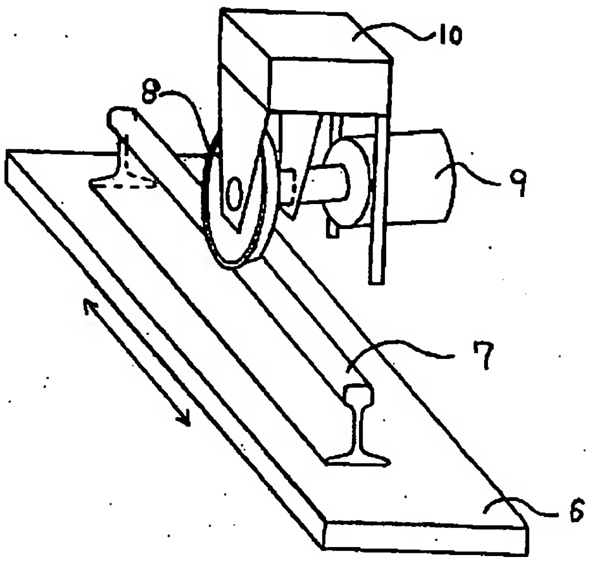
[Drawing 1]



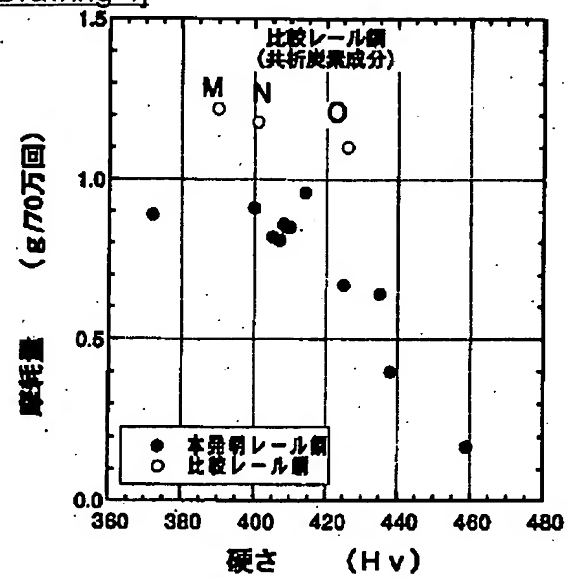
[Drawing 2]



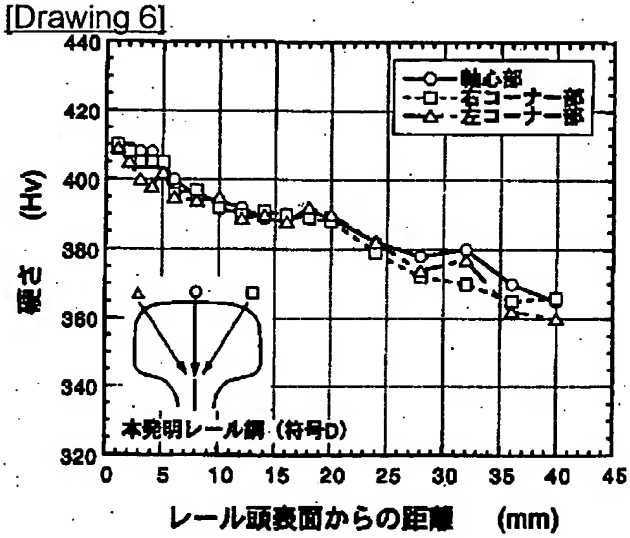
[Drawing 3]



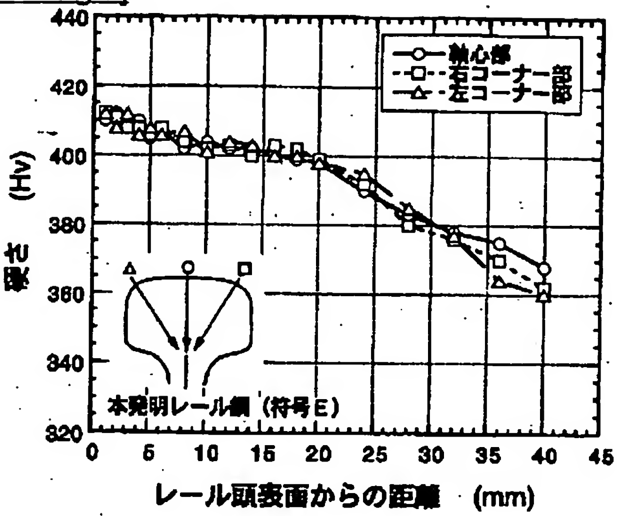
[Drawing 4]



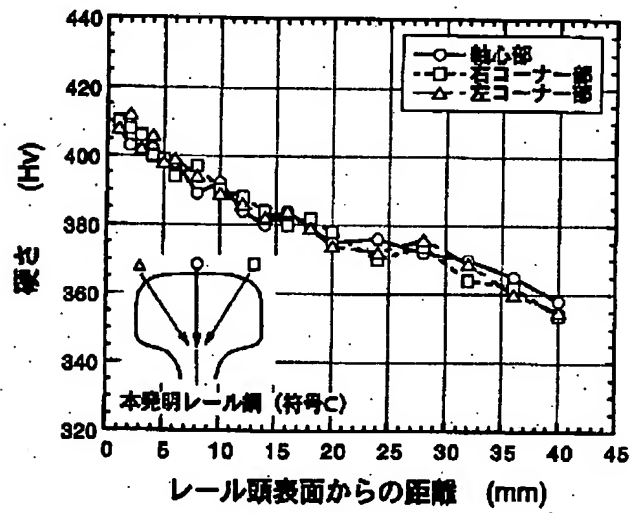
[Drawing 6]



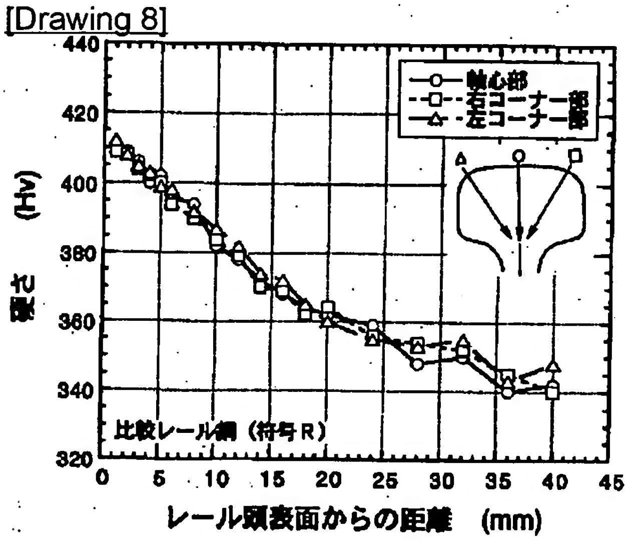
[Drawing 7]



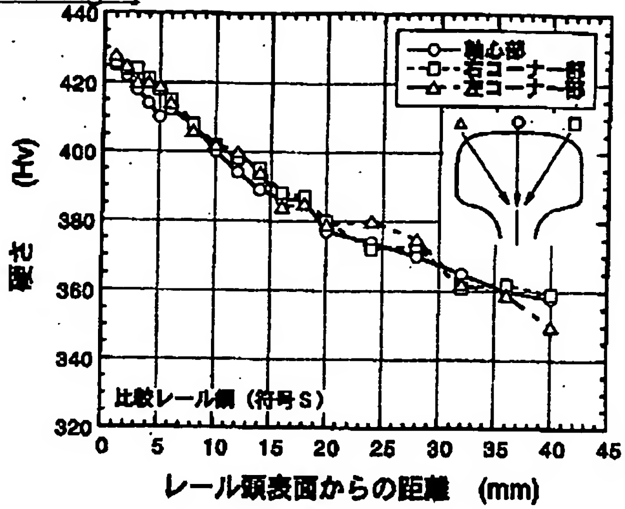
[Drawing 5]



[Drawing 8]



[Drawing 9]



[Translation done.]